# COLORADO
# Yale Avenue

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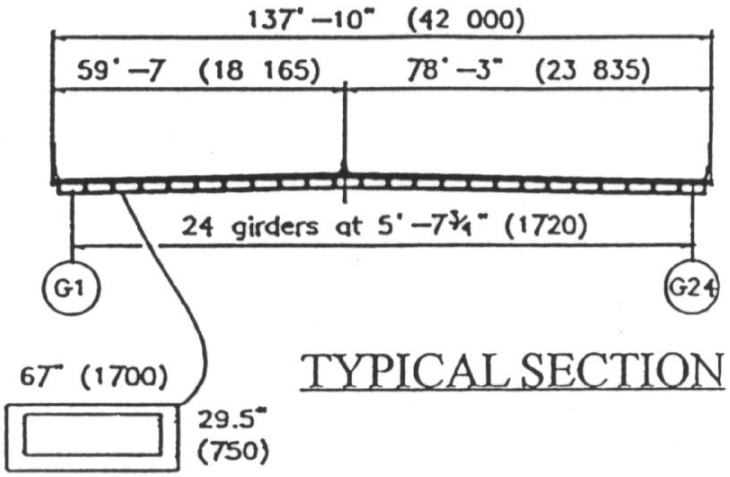
# COLORADO
## Yale Avenue

## 1. DESCRIPTION




| | |
|---|---|
| Location: | Interstate 25 over Yale Avenue, Denver |
| Open to Traffic: | June 1998 |
| Environment: | Normal over road |
| HPC Elements: | Piers, beams, and deck |
| Total Length: | 214 ft 5 in |
| Skew or Curve: | Skew |
| Girder Type: | 1700-mm-wide x 750-mm-deep box beam |
| Girder Span Lengths: | 112 ft 0 in and 97 ft 7 in |
| Girder Spacing: | 1720 mm |
| Girder Strand Grade: | 270 |
| Girder Strand Dia.: | 0.6 in |
| Max. No. of Bottom Strands: | 64 |
| Deck Thickness: | 4-1/2-in precast beams and 175-mm CIP concrete |
| Deck Panels: | None |

## 2. BENEFITS OF HPC AND COSTS

### A. Benefits of HPC

The use of HPC in combination with box beams met the requirements for long spans with a shallow superstructure depth. To provide additional room for a turning lane under the bridge, the HPC bridge used two spans in place of the original four spans. At the same time, it was desirable to improve the vertical clearance over Yale Avenue without significantly changing the existing vertical alignments of I 25 and Yale Avenue. The optimum solution was adjacent precast concrete box beams. To obtain the prestressing force, 0.6-in-diameter strands at 2-in spacings were necessary. The new bridge is 138-ft wide and has one pier with four columns. The previous bridge was 110-ft wide and had three piers and a total of 45 columns. As a result, the new bridge has improved aesthetics and sight distances.

### B. Costs

Girders: $617.6/m erected

## 3. STRUCTURAL DESIGN

| | |
|---|---|
| Design Specifications: | AASHTO Standard Specifications for Highway Bridges, 1996 |
| Design Live Loads: | HS 25-44 |
| Seismic Requirements: | None |
| Flexural Design Method: | AASHTO Standard Specifications 9.17 modified for partial strain compatibility |
| Maximum Compressive Strain: | 0.003 |
| Shear Design Method: | AASHTO Standard Specifications 9.20 |
| Fatigue Design Method: | None |
| Lateral Stability Considerations: | Not applicable |
| Allowable Tensile Stress | |
| —Top of Girder at Release: | $7.5\sqrt{f'_{ci}}$ = 605 psi |
| —Bottom of Girder after Losses: | $6.0\sqrt{f'_{c}}$ = 600 psi |
| Prestress Loss: | 51,772 and 65,753 psi for short and long spans, respectively |
| Method Used for Loss: | Similar to AASHTO Standard Specifications 9.16.2.1 |
| Calculated Camber: | 3.2 to 6.6 in for short span prior to deck placement<br>5.2 to 10.6 in for long span prior to deck placement |
| Concrete Cover | |
| —Girder: | 1 in |
| —Top of Deck: | 2.5 in |
| —Bottom of Deck: | — |
| —Other Locations: | — |
| Properties of Reinforcing Steel | |
| —Girder: | Grade 60, epoxy coated for steel projecting into the deck |
| —Deck: | Grade 60, epoxy coated |
| Properties of Strand | |
| —Grade and Type: | ASTM A 416, Grade 270 low relaxation |
| —Supplier: | — |
| —Surface Condition: | Generally bright and clean |
| —Pattern: | — |
| —Transfer Length: | 60 diameters = 36 in |
| —Development Length: | AASHTO Standard Specifications 9.28 |

## 4. SPECIFIED ITEMS

### A. Concrete Properties

| | Girders | Deck |
|---|---|---|
| Minimum Cementitious Materials Content: | 660 lb/yd$^3$ | 660 lb/yd$^3$ |
| Max. Water/Cementitious Materials Ratio: | — | 0.44 |
| Min. Percentage of Fly Ash: | — | — |
| Max. Percentage of Fly Ash: | 20 | 10 |
| Min. Percentage of Silica Fume: | — | — |
| Max. Percentage of Silica Fume: | — | — |
| Min. Percentage of GGBFS: | — | — |
| Max. Percentage of GGBFS: | — | — |
| Maximum Aggregate Size: | 3/4 in | 3/4 in |
| Slump: | — | (1) |
| Air Content: | — | 5-8% |
| Compressive Strength | | |
| —Release of Strands: | 6500 psi | — |
| —Design: | 10,000 psi at 56 days | 5076 psi at 28 days |
| Chloride Permeability: (AASHTO T 277) | — | — |
| ASR or DEF Prevention: | — | — |
| Freeze-Thaw Resistance: | — | — |
| Deicer Scaling: | — | — |
| Abrasion Resistance: | — | — |
| Other: | — | — |

(1) Not more than 1.5 in greater than slump of the approved mix design.

## B. Specified QC Procedures

| | |
|---|---|
| **Girder Production** | |
| Curing: | — |
| Internal Concrete Temperature: | — |
| Cylinder Curing: | — |
| Cylinder Size: | — |
| Cylinder Capping Procedure: | — |
| Cylinder Testing Method: | — |
| Frequency of Testing: | — |
| Other QA/QC Requirements: | — |
| **Deck Construction** | |
| Curing: | May – Sept. Membrane curing followed by 5 days of water curing<br>Nov. – March. Membrane curing followed by 5 days of insulated blankets<br>April and October. Either of the above methods |
| Cylinder Curing: | — |
| Cylinder Size: | — |
| Flexural Strength: | — |
| Other QA/QC Requirements: | — |

## 5. CONCRETE MATERIALS

### A. Approved Concrete Mix Proportions

| | Girders | CIP Deck |
|---|---|---|
| Cement Brand: | Southwestern | Dacotah |
| Cement Type: | III | — |
| Cement Composition: | — | — |
| Cement Fineness: | — | — |
| Cement Quantity: | 730 lb/yd$^3$ | 418 kg/m$^3$ |
| GGBFS Brand: | — | — |
| GGBFS Quantity: | — | — |
| Fly Ash Brand: | — | — |
| Fly Ash Type: | — | — |
| Fly Ash Quantity: | — | — |
| Silica Fume Brand: | W. R. Grace | — |
| Silica Fume Quantity: | 35 lb/yd$^3$ | — |
| Fine Aggregate Type: | — | — |
| Fine Aggregate FM: | — | — |
| Fine Aggregate SG: | — | — |
| Fine Aggregate Quantity: | 1363 lb/yd$^3$ | 524 kg/m$^3$ |
| Intermediate Aggregate Max Size: | — | — |
| Intermediate Aggregate Type: | — | — |
| Intermediate Aggregate SG: | — | — |
| Intermediate Aggregate Quantity: | — | 297 kg/m$^3$ |
| Coarse Aggregate, Max. Size: | 3/8 in | 3/4 in |
| Coarse Aggregate Type: | — | No. 67 |
| Coarse Aggregate SG: | — | — |
| Coarse Aggregate Quantity: | 1775 lb/yd$^3$ | 883 kg/m$^3$ |
| Water: | 219 lb/yd$^3$ | 158 kg/m$^3$ |
| Water Reducer Brand: | WRDA 64 | — |
| Water Reducer Type: | A and D | — |
| Water Reducer Quantity: | 15-58 fl oz/yd$^3$ | — |
| High-Range Water-Reducer Brand: | WRDA 19 | Master Builders |
| High-Range Water-Reducer Type: | A and F | — |
| High-Range Water-Reducer Quantity: | 44-131 fl oz/yd$^3$ | 730 ml/m$^3$ |
| Retarder Brand: | — | — |
| Retarder Type: | — | — |
| Retarder Quantity: | — | — |
| Corrosion Inhibitor Brand: | — | — |
| Corrosion Inhibitor Type: | — | — |
| Corrosion Inhibitor Quantity: | — | — |
| Air Entrainment Brand: | — | Master Builders |
| Air Entrainment Type: | — | — |
| Air Entrainment Quantity: | — | 133 ml/m$^3$ |
| Water/Cementitious Materials Ratio: | 0.29 | 0.38 |

**B. Measured Properties of Approved Mix**

| | Girders | Deck |
|---|---|---|
| Slump: | 4-9 in | 76 mm |
| Air Content: | 0-1.6% | 6.6% |
| Unit Weight: | 150-152 lb/ft$^3$ | 2244 kg/m$^3$ |
| Initial Set: | 4 hours | — |
| Compressive Strength: | 7500 psi at release<br>8000 psi at 7 days<br>9600 psi at 28 days<br>9900 psi at 56 days<br>10,100 psi at 90 days | 46.9 MPa at 28 days |
| Flexural Strength: | 765 psi at release<br>825 psi at 7 days<br>813 psi at 14 days<br>1150 psi at 28 days<br>1156 psi at 56 days | — |
| Splitting Tensile Strength: | 556 psi at 7 days<br>602 psi at 14 days<br>631 psi at 28 days<br>667 psi at 56 days | — |
| Modulus of Elasticity: | 4210 ksi at release | — |
| Shrinkage: | 444 millionths at 88 days | — |
| Creep: | 0.437 millionths/psi at 88 days | — |
| Chloride Permeability: (AASHTO T 277) | — | — |

# 6. CONCRETE MATERIAL PROPERTIES

## A. Measured Properties from QC Tests of Production Concrete for Girders

| | |
|---|---|
| Cement Composition: | — |
| Actual Curing Procedure for Girders: | — |
| Average Slump: | — |
| Maximum Girder Temperature: | 158 $^{o}$F |
| Air Content: | — |
| Unit Weight: | — |
| Compressive Strength: | 5600 to 10,900 psi at release<br>7800 to 14,000 psi at 56 days |
| Curing Procedure for Cylinders: | — |

## B. Measured Properties from QC Tests of Production Concrete for Deck

| | |
|---|---|
| Cement Composition: | — |
| Actual Curing Procedure for Deck: | 5 days moist cure |
| Curing Procedure for Cylinders: | 5 days moist cure |

Slump, Air Content, Unit Weight, and Compressive Strength:

| Sample No. (2) | Slump (3), mm | Air Content (4), % | Unit Weight (5), kg/m$^3$ | Compressive Strength (6), MPa | | | |
|---|---|---|---|---|---|---|---|
| | | | | 7 days | 28 days | 56 days | 90 days |
| 1 | 108 | 5.2 | 2286 | 28.9 | 35.3 | 39.1 | 40.7 |
| 2 | 89 | 5.3 | 2294 | 32.1 | 37.7 | 42.9 | 42.8 |
| 3 | 95 | 6.0 | 2310 | 29.8 | 36.7 | 41.0 | 41.9 |
| Average | 97 | 5.5 | 2297 | 30.3 | 36.6 | 41.0 | 41.8 |

(2) AASHTO T 141.
(3) AASHTO T 119.
(4) AASHTO T 152.
(5) AASHTO T 121.
(6) AASHTO T 22.

## C. Measured Properties from Research Tests of Production Concrete for Girders

Properties were obtained for concrete representing two girders identified as Girders 1 and 2.

Compressive Strength, Modulus of Elasticity, and Splitting Tensile Strength:

| Curing (7) | Girder No. | Age, days | | | | |
|---|---|---|---|---|---|---|
| | | 7 | 14 | 28 | 56 | 90 |
| Compressive Strength, psi (8) | | | | | | |
| Air | 1 | 7980 | 8130 | 8910 (9) | 8630 | 9010 (9) |
| | 2 | 7650 | 9980 | 9210 | 9820 | 10,720 (9) |
| Moist | 1 | 8650 | 10,010 | 10,180 | 10,750 | 9690 (9) |
| | 2 | 7890 | 10,410 | 10,060 | 10,220 | 10,970 |
| Modulus of Elasticity, ksi (8) | | | | | | |
| Air | 1 | 5000 | 5000 | 6000 (9) | 5000 | 5000 (9) |
| | 2 | 5000 | 5500 | 6500 | 5000 | 5000 (9) |
| Moist | 1 | 5000 | 5500 | 5000 | 6000 | 6000 (9) |
| | 2 | 5000 | 6000 | 5500 | 6000 | 6000 |
| Modulus of Rupture, (ASTM C 78), psi (10) | | | | | | |
| Air | 1 | 775 | 860 | 975 | 1085 | — |
| | 2 | 835 | 835 | — | — | — |
| Moist | 1 | — | 735 | 1185 | 1115 | — |
| | 2 | — | 815 | 1290 | 1285 | — |
| Splitting Tensile Strength (ASTM C 496), psi (11) | | | | | | |
| Air | 1 | 495 | 530 | 525 | 565 | — |
| | 2 | 525 | 515 | 485 | 550 | — |
| Moist | 1 | 620 | 680 | 755 | 750 | — |
| | 2 | 600 | 710 | 755 | 815 | — |

Test results are the average of two specimens except as noted.
(7) Air-cured specimens were steam cured with the girders followed by air curing in the laboratory. Moist cured specimens were cured in a fog room from the beginning.
(8) 4x8-in cylinders.
(9) Single test result.
(10) 3x3x11.5-in beams.
(11) 6x12-in cylinders.

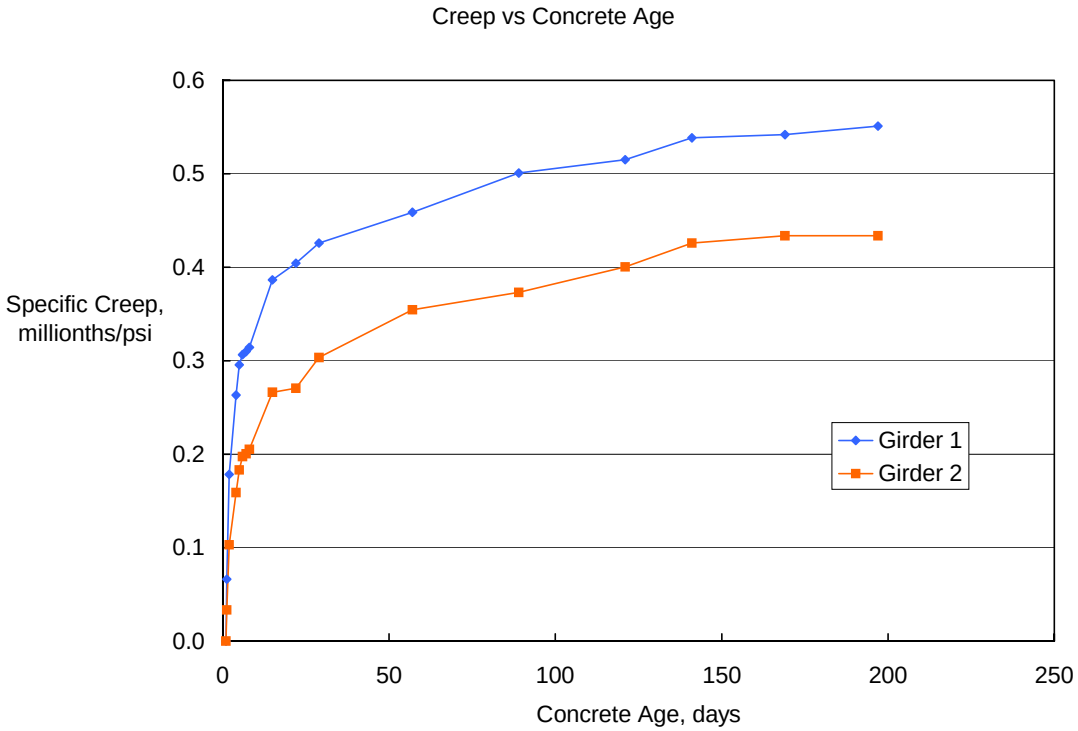
Creep and Shrinkage

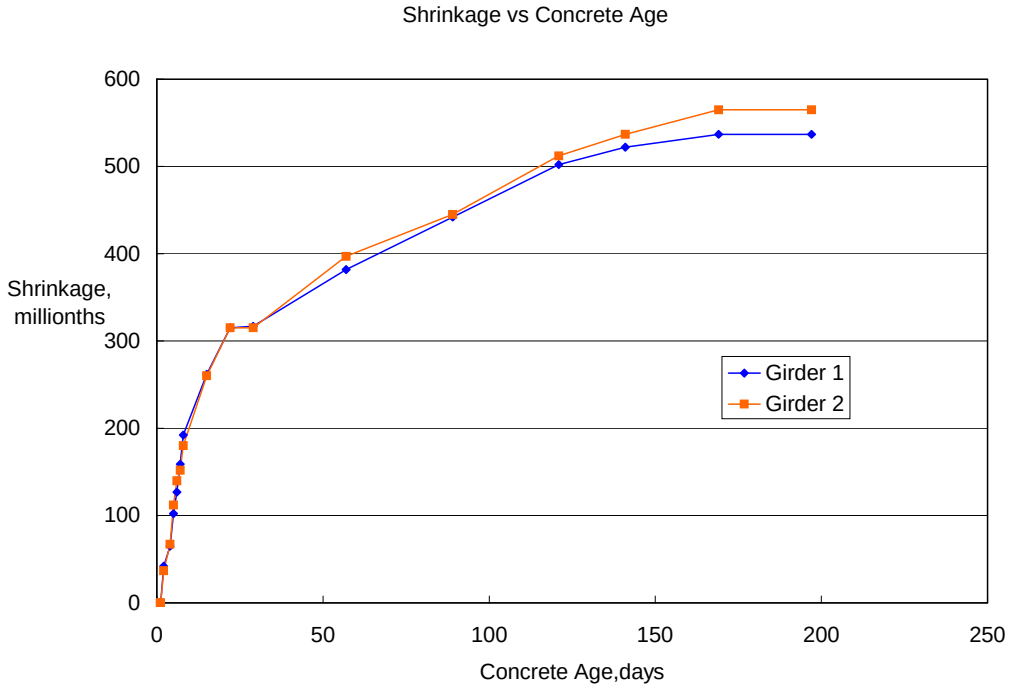
Specimen: 4x8-in cylinders

Loading: 2800 applied at concrete age of 1 day

Curing: Steam cured with girders followed by curing at 73 $^{o}$F 50% RH

See Excel file for data.



## D. Measured Properties from Research Tests of Production Concrete for Deck

Modulus of Elasticity:
(ASTM C 469)

| Sample No. | Age, days | Comp. Strength, MPa | Modulus of Elasticity, MPa |
|---|---|---|---|
| 1 | 28 | 38.4 | 27,400 |
| 2 | 28 | 38.8 | 28,000 |

Measured on 152x305-mm cylinders.

Chloride Permeability:
(AASHTO T 277)

| Laboratory | Permeability, coulombs | | Test Date |
|---|---|---|---|
| | Individual | Average | |
| CTL | 6211, 5334, 5246 | 5597 | 6/20/97 |
| FHWA | 4264, 4617 | 4440 | 11/25/97 |
| CU, Boulder | 3797, 3904 | 3850 | 12/25/97 |
| | 2945, 3005 | 2975 | 1/4/98 |

Abrasion Resistance:
(ASTM C 779, Procedure A)

| Sample No. (12) | Depth of Wear, mm | |
|---|---|---|
| | 30 min. | 60 min. |
| 1 | 0.66 | 1.19 |
| 2 | 0.66 | 1.22 |
| 3 | 0.61 | 1.14 |
| Average | 0.64 | 1.14 |

(12) Test performed at a concrete age of 42 days.

## 7. OTHER RESEARCH DATA

Not available.

## 8. OTHER RELATED RESEARCH

Prior to construction of the bridge, tests were made using 0.6-in-diameter strand at 2-in centers to determine pullout strength, strand transfer length, and strand development length. The strand properties were as follows:

Modulus of Elasticity: 28,700 ksi
Ultimate Strength: 275 ksi
Phosphate Coating: 5.7 $g/m^2$
Concrete Mix Proportions:

| Material | Quantity |
|---|---|
| Type II Cement | 800 $lb/yd^3$ |
| Silica Fume | 30 $lb/yd^3$ |
| 3/8 in Gravel | 1570 $lb/yd^3$ |
| Sand | 1320 $lb/yd^3$ |
| Water | 263 $lb/yd^3$ |
| Water Reducer (Polyheed 997) | 100 fl $oz/yd^3$ |
| High-Range Water-Reducer (Rheobuild 1000) | 120-200 fl $oz/yd^3$ |

Compressive Strength, Modulus of Elasticity, and Modulus of Rupture:

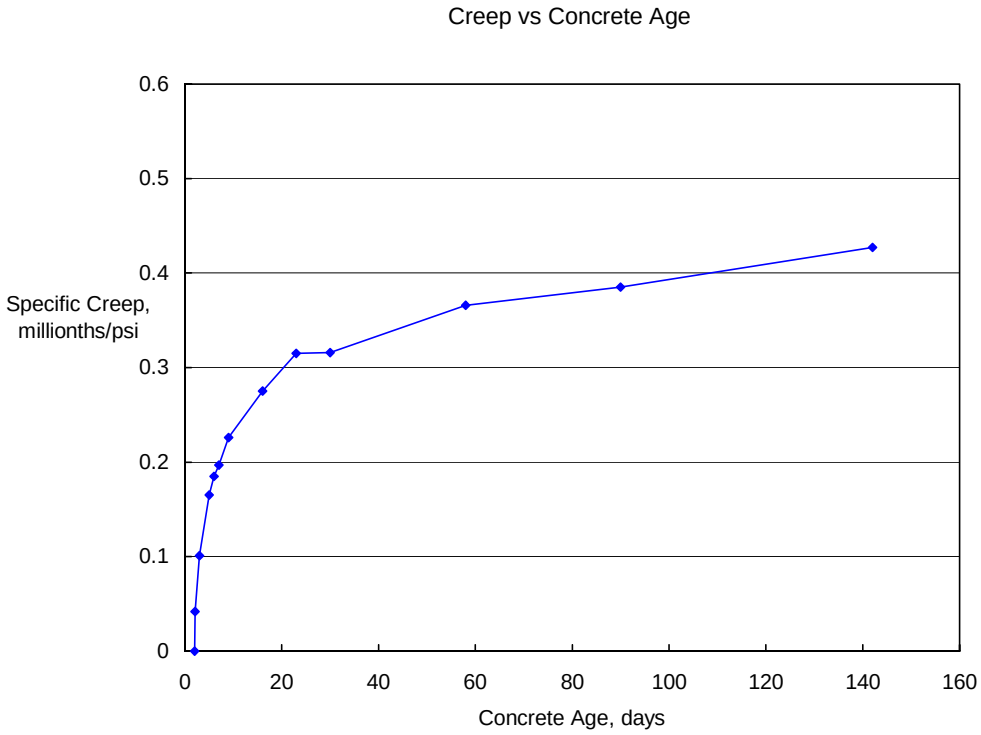
| Age, days | Compressive Strength, psi | | Modulus of Elasticity, ksi | | Modulus of Rupture, psi | |
|---|---|---|---|---|---|---|
| | Air | Moist | Air | Moist | Air | Moist |
| Girder Concrete | | | | | | |
| 2 | 7780 | — | 4700 | 4100 | — | — |
| 3 | — | — | — | — | 600 | 1000 |
| 7 | 8920 | 8900 | 4300 | 4700 | 1000 | 1000 |
| 15 | 9270 | 9870 | 4700 | 5150 | 1000 | 1100 |
| 28 | 8900 | 10,310 | 4550 | 5350 | 1100 | 1200 |
| 50 | 9760 | 10,470 | 4550 | — | — | — |
| 65 | 9680 | 11,220 | 4400 | 5600 | 1100 | 1200 |
| 79 | 9250 | 12,100 | 4250 | 5250 | 1100 | 1200 |
| 90 | 10,060 | 11,040 | — | — | — | — |
| Topping Concrete | | | | | | |
| 7 | 7020 | 7000 | — | — | — | — |
| 14 | 7880 | 7300 | — | — | — | — |
| 28 | 6860 | 6270 | — | — | — | — |
| 43 | 7810 | 7350 | 4500 | — | — | — |
| 58 | 7800 | 8220 | 4550 | 4750 | — | — |
| 72 | 7880 | 8330 | 4500 | 5750 | — | — |

Reported results are for single cylinders or the average results of two cylinders.

Creep

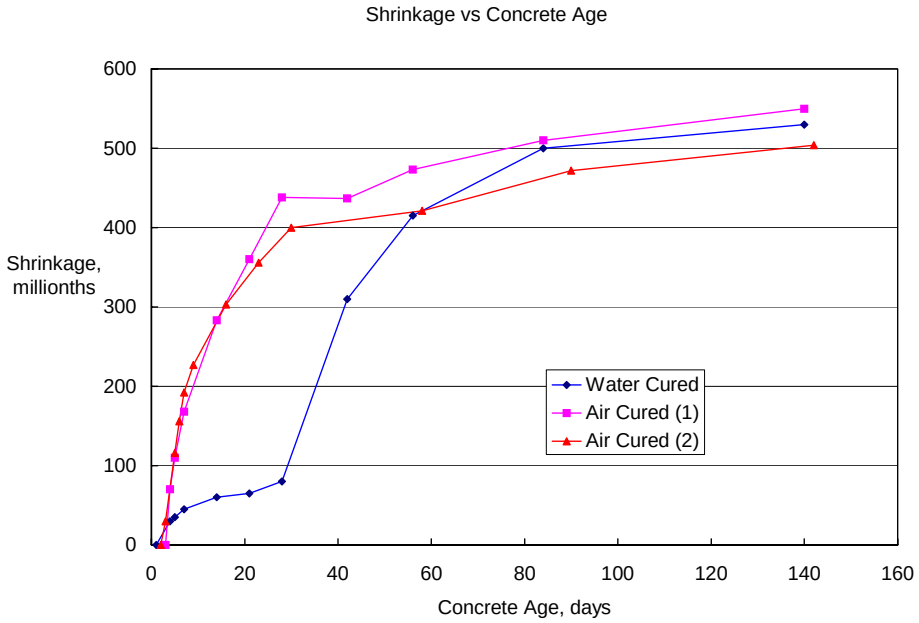
| | |
|---|---|
| Specimens: | 4x8-in cylinders |
| Loading: | 2800 psi at concrete age of 2 days |
| Curing: | Steam cured initially followed by curing at 73 $^{o}$F 50% RH |

See Excel file for data.



Shrinkage
Specimens: 3x3x11-in prisms
Curing: Water cured—28 days water followed by air cure
Air Cured (1)—Heat cured with girders, two days in water followed by air curing
Air Cured (2)—Heat cured with girders followed by air curing

See Excel file for data.




Strand Pullout Tests:

Strand pullout tests were performed using the method developed by Moustafa. A total of eight strand samples, approximately 6-ft long, were embedded to a depth of 18 in in a 24-in-deep, 36-in-long, and 24-in-wide concrete block. Tests were conducted at a concrete age of two days. Measured concrete compressive strength at the test age was 8200 psi. Test results were as follows:

| Strand Number | Load, kip | |
|---|---|---|
| | First Slip | Maximum |
| 1 | 28.8 | 47.1 |
| 2 | 27.8 | 42.5 |
| 3 | 32.7 | 43.2 |
| 4 | 30.1 | 42.5 |
| 5 | 24.9 | 49.1 |
| 6 | 29.4 | 50.4 |
| 7 | 22.9 | 54.3 |
| 8 | 27.5 | 50.4 |
| 9 | 46.4 | 55.6 |
| Average | 30.1 | 48.3 |

Transfer Length:

Transfer length was determined by measuring strains on the girder surface at the level of the center of gravity of nine strands in three 15-in-wide by 19-in-deep hollow beams. Transfer length was determined at a strain corresponding to 95 percent of the average maximum strain. Measured transfer lengths were as follows:

| Girder No. and End | Transfer Length, in | |
|---|---|---|
| | Release at 2 days | 28 days |
| 1-E | 24.2 | 28.3 |
| 1-W | 24.4 | 26.4 |
| 2-E | 22.0 | 22.0 |
| 2-W | 23.8 | 25.6 |
| 3-E | 23.8 | 25.6 |
| 3-W | 21.9 | 21.7 |
| Average | 23.4 | 24.9 |

The average measured end slip at transfer was 0.06 in.

Development Length:

Development length tests were made on the same beams used for transfer length measurements but with a 2-3/4-in-thick concrete topping added at a girder age of 7 days. The development test results were as follows:

| Girder No. and End | Concrete Comp. Strength, psi | | Embedment Length, in | Failure Moment, kip-ft | Failure Type |
|---|---|---|---|---|---|
| | Girder | Slab | | | |
| 1-E | 11,000 | 7900 | 85 | 925 | Flexure |
| 1-W | 11,100 | 8000 | 81 | 907 | Flexure |
| 2-W | 11,200 | 8000 | 76 | 967 | Flexure/Slip |
| 2-E | 11,200 | 8000 | 65 | 857 | Flexure/Slip |
| 3-E | 11,200 | 8000 | 60 | 895 | Slip/Shear |
| 3-W | 11,200 | 8000 | 59 | 848 | Slip/Flexure/Shear |

## 9. SOURCES OF DATA

Shing, P. B., Cooke, D. E., Frangopol, D. M., Leonard, M. A., McMullen, M. L., and Hutter, W., "Strand Development and Transfer Length Tests on High Performance Concrete Box Girders," *PCI Journal*, Vol. 45, No. 5, September/October 2000, pp. 96-109.

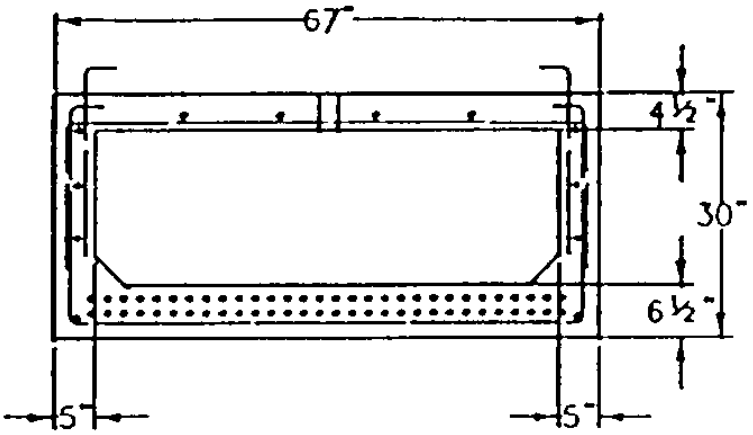
Colorado High Performance Concrete Showcase Notebook, Denver, CO, February 18-20, 1998.

Cooke, D. E., Shing, P. B., and Frangopol, D. M., "Colorado Study on Transfer and Development Length of Prestressing Strand in High Performance Concrete Box Girders," Report No. CDOT-DTD-R-98-7, Colorado Department of Transportation, Denver, CO, 1998.

Mark A. Leonard, Colorado Department of Transportation, Denver, CO.

P. Benson Shing, University of Colorado, Boulder, CO.

## 10. DRAWINGS




Girder Section

# 11. HPC SPECIFICATIONS

COLORADO PROJECT NO. HB 0252-297 Oct. 23, 1996

REVISION OF SECTION 105
CONCRETE DEMONSTRATION

Section 105 of the Standard Specifications is hereby revised for this project as follows:

Subsection 105.05 shall include the following:

The design and construction of the I25 over Yale Avenue bridge is part of a federal demonstration project on the use of high performance concrete (HPC) by the Colorado Department of Transportation. This demonstration is a cooperative effort between the Federal Highway Administration, the University of Colorado, and the Colorado Department of Transportation. A HPC demonstration team has been established with representatives from these three agencies for the demonstration project.

All aspects of the demonstration team's work will be coordinated with the Contractor through the Project Engineer. During construction, coordination between the Contractor and subcontractors with the demonstration team will be required to ensure adequate access during girder fabrication and bridge construction for installation of the instrumentation shown in the plans, data collection, concrete sampling, and documentation of construction.

A schedule for the following events, critical to the instrumentation and data collection, shall be submitted at least 2 weeks prior to each event. Department personnel including representatives from the HPC team will be present at these events and shall be provided with access as necessary to install the instrumentation shown in the plans, collect data, and obtain concrete samples. The Engineer shall be notified immediately of any changes to the schedule. Less than forty-eight hour notice of any changes may require a delay to the Contractor which will not be the responsibility of the Department.

1. Girder S1G17 (span-1 girder-17), S1G18, and S2G18 rebar placement started, allowing instrumentation installation to begin.
2. Concrete placement for girders S1G17, S1G18, and S2G18.
3. Stand release for girders S1G17, S1G18, and S2G18.
4. Removal of girders S1G17, S1G18, and S2G18 from the casting bed.
5. Transportation to, and erection of girders S1G17, S1G18, and S2G18 at the bridge site.
6. Phase 1 deck rebar placement started, allowing instrumentation installation to begin.
7. Phase 1 bridge deck concrete placement.
8. Phase 1 bridge construction opening to traffic.

REVISION OF SECTION 105
CONCRETE DEMONSTRATION

Additional time will be required for the fabrication of girders S1G17, S1G18, and S2G18. The Contractor shall provide up to two days for each casting involving any one of these three girders. The Contractor shall provide up to one full working day for a large group tour of the construction site, to be arranged by the Engineer.

The Department will take samples, at least four per test, for the following tests. These tests, to be performed by the Department, will be for documentation purposes and are in addition to the normal testing as required by this contract.

Phase 1 bridge deck concrete:

28 Day Compressive Strength
56 Day Compressive Strength
90 Day Compressive Strength
Chloride Permeability
Freeze/Thaw Durability
Abrasion Resistance
Shrinkage
Creep
Elasticity

S1G17, S1G18, and S2G18 girder concrete:

Compressive strength at release
28 Day Compressive Strength
56 Day Compressive Strength
90 Day Compressive Strength
Shrinkage
Creep
Elasticity
Modulus of Rupture
Splitting Tensile Strength

The Contractor and Subcontractors shall take adequate measures to protect and prevent damage to the instrumentation and associated wires. This is especially critical during the girder pour, whenever the girders are moved, during deck rebar placement, and when placing the deck concrete. Any instrumentation or wiring damaged by the Contractor shall be repaired at the Contractor's expense.

During bridge construction the wiring will be routed to the instrumentation box shown in the plans at the Northwest corner of the bridge. The Contractor shall maintain Department access to the instrumentation box from the time of phase 1 deck rebar placement through the duration of the project.

# REVISION OF SECTION 601
## STRUCTURAL CONCRETE

Section 601 of the Standard Special Provisions is hereby revised for this project as follows:

In Subsection 601.02, Table 601-1 delete the requirements for Class D and Class S and replace with the following:

Table 601-1 Concrete Table

| Concrete Class | Required 28 Day Field Compressive Strength psi (MPa) | Cement Content (lbs/cubic yard) | Air Content % Range (Total) | Additional Requirements |
|---|---|---|---|---|
| D | 5076 (35 MPa) | 660 (400 kg/$m^3$) | 5-8 | (3)(5)(8)(10) |
| S | (6)(11) | 660 (400 kg/$m^3$) | (6) | (5)(8)(10) |

Subsection 601.02, Table 601-1, shall include the following footnote:

(11) The acceptance criteria for Class S concrete used in precast girders shall be based on 56 day field compressive strength.

In Subsection 601.05, Proportioning, delete the fifth sentence from the first paragraph and replace with the following:

The design mix proportions must produce 28 day compressive strengths at least 114 percent of the required 28 day field compressive strengths.

# REVISION OF SECTION 618
# PRESTRESSED CONCRETE

Section 618 of the Standard Specifications is hereby revised for this project as follows:

Subsection 618.03 shall include the following:

The Contractor submittal of design mix proportions, laboratory trial mix and aggregate data contained in the revision of Subsection 601.05 shall apply to the Concrete Class S used in precast concrete girders except the tests shall be based on 56 day test results instead of 28 days.

The record of the jacking forces and elongations contained in Subsection 618.06(b) shall be submitted to the Engineer for project documentation of the instrumented girders S1G17 (span-1 girder-17), S1G18, and S2G18.

Instrumentation as indicated in the plans shall be provided and installed by the Department in girders S1G17, S1G18, and S2G18. The presence of this instrumentation shall be noted in the shop drawings. The Contractor and fabricator shall make the necessary provisions to allow for installation of instrumentation, data collection, and concrete sampling as provided for in the revision of Subsection 105.05. The Department will require access at the following times during fabrication and erection of girders S1G17, S1G18, and S2G18.

1. Between steel reinforcement placement and final form erection, for installation of embedded instrumentation.
2. At concrete placement, for obtaining concrete samples.
3. Between form removal and release of prestressing strands, for reading instruments and establishing baseline camber measurements.
4. Between release of prestressing stands and removal of girders from the beds, for reading instruments and making camber measurements. Department personnel shall be present when the girders are moved from the beds.
5. During storage, for reading instruments and making camber measurements.
6. During erection, to help ensure correct positioning of girders and instrumentation wiring.

REVISION OF SECTION 601
BRIDGE DECK CONCRETE

Section 601 of the Standard Specifications is hereby revised for this project as follows:

Subsection 601.15 shall include the following:

(g) If cracks in the deck concrete with a width of 0.035" (0.9 mm) or greater occur within two weeks of placement those cracks shall be repaired at the Contractor's expense. Cracks will be measured by the Engineer by insertion of a wire gauge at any time and temperature within the two weeks. The repair shall consist of filling the cracks with a low viscosity, two part methacrylate or an approved equal. The repair shall be in accordance with the recommendations of the manufacturer of the crack filling material.

In Subsection 601.16, delete the third paragraph and delete subsections 601.16(a) and 601.16(b) and replace with the following:

Concrete bridge decks, including bridge curbs and bridge sidewalks shall be cured as follows:

(a) Decks placed from May 1 to September 30 shall be cured by the membrane forming curing compound method followed by the water cure method as follows:

1. Membrane Forming Curing Compound Method. A volatile organic content (VOC) compliant curing compound conforming to AASHTO M 148, Type 2 shall be uniformly applied to the surface of the deck, curbs and sidewalks at the rate of one gallon per 100 square feet (40 L/100 $m^2$). The curing compound shall be applied as a fine spray using power operated spraying equipment The power operated spraying equipment shall be equipped with an operational pressure gage and a means of controlling the pressure. Before and during application the curing compound shall be kept thoroughly mixed by recirculation or a tank agitator. The application shall be within 20 feet (6 m) of the deck finishing operation. When the finishing operation is discontinued, all finished concrete shall be coated with curing compound within 1/2 hour. The curing compound shall be thoroughly mixed within one hour before use.

2. Water Cure Method. The water cure method shall be applied as soon as it can be without marring the surface and shall be continued for five days. The surface of the concrete, including bridge curbs and bridge sidewalks, shall be entirely covered with cotton, burlap, or combination polyethylene sheeting and burlap mats. Approved combinations of a barrier and a water retaining layer may be used. Prior to being placed, the mats shall be thoroughly saturated with water. The mats shall extend at least twice the thickness of the bridge deck beyond the edges of the slab and shall be weighted to remain in contact with the surface. The mats shall remain in contact and be kept wet for a minimum of five days after concrete placement.

(b) Decks placed between November 1 and March 31 shall be cured by application of a membrane forming curing compound followed by the blanket method as follows:

1. Membrane Forming Curing Compound Method.. This method shall be applied in accordance with 601.16(a)1 above.

2. Blanket Method. Curing blankets with a minimum R-Value of 0.5 shall be placed on the deck as soon as they can be without marring the surface. Blankets shall be loosely laid (not stretched) and adjacent edges suitably overlapped with continuous weights along the lapped joints. The blankets shall remain in place for a minimum of five days after placement.

(c) Decks placed in April or October may be cured in accordance with either 601.16(a) or 601.16(b) above.

(d) For decks placed above an elevation of 8,000 feet (2500 m) above mean sea level, the Engineer may modify the time of year requirements for the cure methods defined in 601.16(a) and 601.16(b) above.

REVISION OF SECTION 601
STRUCTURAL CONCRETE

Section 601 of the Standard Specifications is hereby revised for this project as follows:

Delete subsection 601.02 including Table 601-1, and replace with the following:

601.02 Classification. The classes of concrete shown in Table 601-1 shall be used when specified in the Contract.

TABLE 601 -1 Concrete Table

| Concrete Class | Required 28 Day Field Compressive Strength (PSI) | (1) Cement Content (lbs/cu yd) | Air Content % Range (Total) | Additional Requirements |
|---|---|---|---|---|
| B | 3000 (25 MPa) | 565 (335 kg/$m^3$) | 5-8 | (2) (4) (8) (10) |
| D | 4350 (30 MPa) | 615 (365 kg/$m^3$) | 5-8 | (3) (5) (8) (10) |
| P | 4200 (30 MPa) | 565 (335 kg/$m^3$) | 4-8 | (7) (8) |
| S | (6) | 660 (400 kg/$m^3$) | (6) | (5) (8) (10) |
| BZ | 4000 (30 MPa) | 610 (365 kg/$m^3$) | – | (9) (10) |

(1) The cement content tolerance of + or - 1 % specified in AASHTO M 157 will be allowed.
(2) Class D concrete may be substituted for Class B.
(3) Class D concrete requires the use of an approved water reducing admixture.
(4) Class B concrete shall be used when Standard Plans specify Class A concrete.
(5) Bridge deck concrete shall have a total air content of 5 – 8% and a maximum water/cement (w/c) ratio of 0.44. In determining the w/c ratio, the cement (c) shall be the sum of the weight of the cement and the weight of the fly ash.
(6) Strength and air content for Class S concrete will be specified in the Contract.
(7) Class P pavement shall contain a minimum of 55% coarse aggregate. Coarse aggregate shall be No. 467 or No. 357 unless all transverse joints are doweled in which case No. 67 or No. 57 coarse aggregate is acceptable.
(8) The slump of the delivered concrete shall not exceed the slump of the approved concrete mix design by more than 1 1/2 inches (38 mm).
(9) Concrete for caissons shall be Class BZ. Entrained air is not required unless specified in the Contract. High range water reducers may be added at the job site to obtain desired slump and retardation. Admixtures shall conform to subsection 711.03. Slump shall be a minimum of five inches (125 mm) and a maximum of eight inches (200 mm).
(10) Superstructure concrete and Class BZ caisson concrete shall be made with 3/4" (19 mm) nominal sized coarse aggregate: 100% passing the 1" (25.0 mm) sieve and 90% to 100% passing the 3/4" (19 mm) sieve. All other concrete shall have a nominal coarse aggregate size of 1 1/2" (37.5 mm) or smaller: 100% passing the 2" (50 mm) sieve and 95% to 100% passing the 1 1/2" (37.5 mm) sieve.

In subsection 601.03 delete the second, third, and fourth paragraphs.

REVISION OF SECTION 601
STRUCTURAL CONCRETE

Delete subsection 601.05 and replace with the following:

601-05 Proportioning. The Contractor shall submit design mix proportions, laboratory trial mix and aggregate data, for each class of concrete being placed on the project. Concrete shall not be placed on the project before the design mix proportions and data have been reviewed and approved by the Engineer. The test data shall show the mix design proportions, of all ingredients including cement, fly ash, aggregate, and additives, slump, air content, unit weight, yield, water/cement ratio, and 28 day compressive strength results as trialed under laboratory conditions. The test data submitted shall be based on tests conducted by the Contractor and shall not be based on tests conducted by the Department. The design mix proportions must produce 28 day compressive strengths at least 125 percent of the required 28 day field compressive strengths. Each design shall establish the mix proportions and sources of all ingredients. Aggregate test data include gradations, percent passing No. 200 sieve, sand equivalent, fineness modules, specific gravities, absorptions, and LA Abrasion test results. The Contractor shall be responsible for the design mix proportions and all subsequent adjustments necessary to produce the specified concrete. The test data for Class P concrete shall also include 28 day flexural strength results from two beams broken in accordance with AASHTO T 97. The Division may run a trial mix to verify that the design mix meets the requirements of subsection 601.02.

The Contractor shall submit a new design mix that is based on the above requirements when a change occurs in the source, type, or proportions of cement fly ash, or aggregate.

Yield shall be determined in accordance with AASHTO T 121 for each of the following:

(1) The design mix submitted by the Contractor shall be designed to yield 0.995 to 1.01 (26.87 to 27.27 cu. ft/cu. yd. for english units) as determined by the Contractor.

(2) The trial mix conducted by the Contractor shall have a relative yield of 0.99 to 1.02 (26.73 to 27.54 cu. ft/ cu. yd. for english units) as determined by the Contractor.

(3) For paving concrete where cubic yards (cubic meters) is a pay quantity the relative yield of the concrete produced on the project shall be 0.99 to 1.02 (26.73 to 27.54 cu. ft/cu. yd. for english units). If the relative yield of the concrete produced does not conform to this range for two consecutive yield determinations, concrete production shall cease and the Contractor shall present a plan to correct the relative yield to the Engineer.

Review and approval of the design mix by the Engineer does not constitute acceptance of the concrete. Acceptance will be based solely on the test results of the concrete placed on the project.

The Contractor shall have the option of substituting approved fly ash for portland cement up to a maximum of 20 percent by weight in any class of concrete shown in Table 601-1, with the following exceptions: (1) concrete used for bridge decks shall have a maximum substitution of 10 percent and (2) fly ash added to concrete pavements shall be added in accordance with subsection 412.04 which requires the fly ash to be in addition to the full weight of the cement as specified in Table 601-1.

Where the Contractor's voluntary use of fly ash results in any delay, necessary change in admixture quantities or source, or unsatisfactory work, the cost of such delays, changes or corrective actions shall be borne by the Contractor.

In subsection 601.C)6, delete the second paragraph and replace with the following:

The Contractor shall furnish a batch ticket (delivery ticket) with each load for all classes of concrete. Concrete delivered without a batch ticket containing complete information as specified shall be rejected. The Contractor shall collect and complete the batch ticket at the placement site and deliver all batch tickets to the Engineer on a

daily basis. The Engineer shall have access to the batch tickets at any time during the placement. The following information shall be provided on each batch ticket:

(1) Supplier's name and date
(2) Truck number
(3) Project number and location
(4) Concrete class designation and item number
(5) Cubic yards (cubic meters) batched
(6) Time batched
(7) CDOT mix design number
(8) Type, brand, and amount of each admixture
(9) Type, brand, and amount of cement and fly ash
(10) Weights (mass) of fine and coarse aggregates
(11) Moisture of fine and coarse aggregate
(12) Gallons (liters) of batch water (including ice)

The Contractor shall add the following information to the batch ticket at the placement site:

(13) Gallons (liters) of water added by truck operator plus quantity of concrete in the truck each time water is added
(14) Number of revolutions of drum at mixing speed (for truck mixed concrete)
(15) Discharge time
(16) Location of batch in placement
(17) Water cement ratio (required for deck concrete only)

Subsection 601.17(c), first paragraph, shall include the following:

If the compressive strength of any one test cylinder differs from the average by more than 10% that compressive strength will be deleted and the average strength will be determined using the compressive strength of the remaining two test cylinders.

In subsection 601.17(c), second paragraph, after the first sentence add the following:

If less than three strength tests are available the individual low tests, if any, will be used to determine the pay factor in accordance with Table 601-2.